

CLAIMS:

1. A polishing pad for a chemical mechanical planarization (CMP) system,
comprising:
a surface characterized by a polish rate responsive to a pad contact area and
5 pad contact dynamics,
wherein the pad contact area is characterized by a predetermined statistical
distribution of a pad surface height, and
wherein the pad contact dynamics are characterized by a mechanical
behavior of the polishing pad.

10 2. The polishing pad of Claim 1, wherein the predetermined statistical
distribution comprises a sum of a first statistical distribution and a second statistical
distribution.

15 3. The polishing pad of Claim 2, wherein the first statistical distribution
comprises a distribution based on a bulk component of the surface, and wherein the second
statistical distribution comprises a distribution based on a near surface component of the
surface.

20 4. The polishing pad of claim 2,
wherein the first statistical distribution comprises an exponentially
modified Gaussian distribution, and wherein the second statistical distribution comprises a
Gaussian distribution.

5. The polishing pad of Claim 1, wherein the statistical distribution comprises
at least one mathematical distribution selected from the group consisting of a Gaussian
distribution, an exponentially modified Gaussian distribution, and a Pearson distribution.

25 6. The polishing pad of Claim 1, wherein the pad surface height comprises
surface height characterized by a pad height histogram.

7. The polishing pad of Claim 6, wherein the pad surface height comprises a surface height responsive to a geometric average of a surface height data set.

8. The polishing pad of Claim 1, wherein the mechanical behavior comprises behavior responsive to a volumetric displacement of the polishing pad.

5 9. The polishing pad of Claim 1, wherein the mechanical behavior comprises behavior comprises behavior characterized as an elastic spring.

10. The polishing pad of Claim 1, wherein the mechanical behavior comprises behavior characterized by Hooke's Law.

10 11. The polishing pad of Claim 1, wherein the polish rate comprises a rate responsive to an optimal pad contact area.

12. The polishing pad of Claim 11, wherein the optimal pad contact area comprises about 0 percent to about 15 percent.

13. The polishing pad of Claim 11, wherein the optimal pad contact area comprises about 3 percent to about 8 percent.

15 14. The polishing pad of Claim 11, wherein the optimal pad contact area comprises about 6 percent.

15. The polishing pad of Claim 11, wherein the optimal pad contact area comprises an area that varies in response to at least one process parameter.

20 16. The polishing pad of Claim 15, wherein the at least one process parameter comprises a slurry, a wafer type, a platen speed, and a holder speed.

17. The polishing pad of Claim 15, wherein the at least one process parameter comprises at least one physical property of the polishing pad.

18. The polishing pad of Claim 17, wherein the at least one physical property comprises one or more of:

- i. a density greater than about 0.5 g/cm³;
- ii. a tensile modulus of about 0.02 to about 5 GigaPascals;
- iii. a hardness of about 25 to about 80 Shore D;
- vi. a yield stress of about 300 to about 6000 psi;
- iv. a tensile strength of about 1000 to about 15,000 psi; and
- v. an elongation to break up to about 500%.

19. A polishing pad for a chemical mechanical planarization (CMP) system, comprising:

a surface characterized by a polish rate responsive to a predetermined statistical distribution of a pad surface height and a mechanical behavior of the polishing pad, wherein the statistical distribution comprises a first statistical distribution and a second statistical distribution, the first statistical distribution representing a bulk component of the surface the second statistical distribution representing a near surface component of the surface, and

wherein the mechanical behavior is characterized by an elastic spring.

20. The polishing pads of Claim 19, wherein the first statistical distribution comprises an exponentially modified Gaussian distribution, and wherein the second statistical distribution comprises a Gaussian distribution.

21. The polishing pad of Claim 19, wherein the statistical distribution comprises at least one mathematical distribution selected from the group consisting of a Gaussian distribution, an exponentially modified Gaussian distribution, and a Pearson distribution.

22. The polishing pad of Claim 19, wherein the polish rate comprises a rate responsive to an optimal pad contact area.

23. The polishing pad of Claim 22, wherein the optimal pad contact area comprises an area that varies in response to at least one process parameter.

5 24. The polishing pad of Claim 19, wherein the mechanical behavior comprises behavior characterized by Hooke's Law.

10 25. A chemical mechanical planarization (CMP) system, comprising:
a polishing pad disposed on a platen;
a wafer mounted in a holder; and
a slurry disposed between the polishing pad and the wafer,
wherein the holder is operable to press the wafer against a surface of the
polishing pad,
wherein the surface is characterized by a predetermined statistical
distribution of a pad surface height and a mechanical behavior of the polishing pad, and
15 wherein the polishing pad has a polish rate responsive to the pad surface
height distribution and the mechanical behavior.

26. The CMP system of Claim 25, wherein the statistical distribution comprises an exponentially modified Gaussian distribution and a Gaussian distribution.

20 27. The CMP system of Claim 25, wherein the mechanical behavior comprises behavior characterized by Hooke's Law.

28. The CMP system of Claim 25, wherein the polish rate comprises a rate responsive to an optimal pad contact area.

29. The CMP system of Claim 28, wherein the optimal pad contact area comprises about 0 percent to about 15 percent.

30. The CMP system of Claim 25, wherein the polishing pad comprises a thermoplastic material.

31. The CMP system of Claim 30, wherein the thermoplastic material comprises at least one moiety selected from the group consisting of a urethane; a
5 carbonate; an amide; an ester; an ether; an acrylate; a methacrylate; an acrylic acid; a methacrylic acid; a sulphone; an acrylamide; a halide; and a hydroxide.

32. The CMP system of Claim 25, wherein the wafer comprises at least one of an oxide, a metal, a semiconductor, and an alloy.

33. The CMP system of Claim 25, wherein the wafer comprises at least one of
10 Si, SiO₂, GaAs, Cu, Ta, TaN, W, TiN, Ti, and Si₃N₄.

34. The CMP system of Claim 25, wherein the slurry comprises one of an alkaline-based solution and an acid-based solution.

35. The CMP system of Claim 25, wherein the slurry comprises colloidal silica.

36. The CMP system of Claim 25 further comprising a pad conditioner
15 disposed on the polishing pad, the pad conditioner operable to remove pad material from the polishing pad.

37. The CMP system of Claim 36, wherein the polish rate comprises a rate responsive to the removal of pad material by the pad conditioner.

38. The CMP system of Claim 37, wherein the polish rate comprises a rate
20 characterized as rate-saturated conditioning.

39. A polishing pad for a chemical mechanical planarization (CMP) system, comprising:

a surface characterized by a polish rate responsive to a pad contact area and pad contact dynamics,

wherein the pad contact area is characterized by a predetermined statistical distribution of a pad surface height, and

5 wherein the pad contact dynamics are characterized by a frictional loading factor and a pressure force.

40. The polishing pad of claim 39, wherein the pressure force is characterized by the Sommerfeld number.

10 41. The polishing pad of claim 40, wherein the Sommerfeld number ranges from about 0 to about 3.

42. The polishing pad of claim 39, wherein the frictional loading factor is represented by the expression $\mu V/P_c$, where P_c is an applied pressure by the polishing pad to a wafer divided by the pad contact area, V is a relative velocity between the wafer and the polishing pad, and μ is a slurry viscosity.

15 43. The polishing pad of claim 39, wherein the pad contact area is responsive to pad conditioning of the surface by a pad conditioner.

44. The polishing pad of claim 43, wherein the pad conditioner comprises a conditioner having diamond crystals with a spatial density ranging from about 1 per square millimeter to about 100 per square millimeter.

20 45. The polishing pad of claim 44, wherein the diamond crystals comprise crystals having geometric configurations selected from the group consisting of angular, block, mosaic, and cubo-octahedral.

46. The polishing pad of claim 44, wherein the diamond crystals have nominal diameters in the range of about 20 to about 500 μm .

47. The polishing pad of claim 43, wherein the pad conditioner is characterized by a pad material removal rate of between about 0 to about 200 $\mu\text{m}/\text{hour}$.